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14. ABSTRACT
In addition to the completed doctoral dissertations listed above, various other projects were also begun. One which has been completed was the Quick-Look Tool for Tanker Deployment,
a project undertaken at the request of AMC/XPY. In addition, yet another doctoral dissertation was in the process of being completed, the: Strategic Brigade Airdrop Simulation and Analysis Project.
Furthermore, we have also started on a major effort to combine seamlessly and in a novel way simulation and optimization of the airlift network problems of AMC and TRANSCOM. We expect that effort to culminate in a doctoral dissertation as well.
Finally, we established a working relationship with the MDPFR organization
(Medical Defense Project in Reinvention) under the initiative of the USAF
Command Surgeon's office. We intend to undertake some joint projects with them
to improve medical services for the DOD.

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FINAL PROJECT REPORT

Submitted to
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By

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In connection with

Grant AFOSR F49620-99-1-0073

AIR TRANSPORTATION NETWORK ROUTING AND SCHEDULING

Due February 28, 2002

INTRODUCTION

This is a late Final Report on the project:

AIR TRANSPORTATION NETWORK ROUTING AND SCHEDULING

While we cannot offer an explanation for the lateness of this report other than that it was an unfortunate oversight on the part of the P.I., we would mention here that since the principal results of the project were doctoral dissertations, 3 copies each of these dissertations were mailed to the AFOSR promptly upon their completion. Therefore, for the purposes of this Final Report, we are appending here only the Abstracts of these dissertations.

OBJECTIVES.

To support faculty, as well as graduate and undergraduate students, to develop improved methodologies for the scheduling and routing of military transport aircraft; and to do so in collaboration with personnel from Flight XPY at the USAF Air Mobility Command, Scott AFB, IL; and/or the US Transportation Command, also at Scott AFB, IL.

STATUS OF EFFORT.

The various joint projects undertaken were presented and discussed at frequent periodic meeting between the personnel of HQ/AMC/XPY and members of the Center for Optimization and Semantic Control at Washington University. Reports of these discussions were also regularly provided to AFOSR.

ACCOMPLISHMENTS/NEW FINDINGS

Our principal accomplishments are embodied in doctoral dissertations and in published papers. Copies of all of these items are sent to the AFOSR as soon as they become available. In particular, we presented in this fashion three doctoral dissertations:

1. Tunay, I: Extremum-Seeking Based Antiskid Control and Functional Principal Components;

2. Kim, S: Adaptations of Constraint Programming to Aircraft Scheduling Problems;

3. Cusick, T: Simulation and Optimization of a Military Airfield System.

In addition to the completed doctoral dissertations listed above, various other projects were also begun. One which has been completed was the

Quick-Look Tool for Tanker Deployment,

a project undertaken at the request of AMC/XPY. In addition, yet another doctoral dissertation was in the process of being completed, the:

Strategic Brigade Airdrop Simulation and Analysis Project.

Furthermore, we have also started on a major effort to combine seamlessly and in a novel way simulation and optimization of the airlift network problems of AMC and TRANSCOM. We expect that effort to culminate in a doctoral dissertation as well.

Finally, we established a working relationship with the MDPR organization (Medical Defense Project in Reinvention) under the initiative of the USAF Command Surgeon's office. We intend to undertake some joint projects with them to improve medical services for the DOD.

PERSONNEL ASSOCIATED WITH THIS RESEARCH (during various periods)

Faculty:

Professors Ervin Y. Rodin (PI)
S. Massoud Amin
Vaidyanathan Sundarapandian

Students:

Travis Cusick	Ilker Tunay
Greg Grindey	Brian Russina
Eugene Day	Christiana Russ
Sanghyun Kim	Ilker Tunay
Brandy Ruthsatz	

Note: While each of the students above participated and contributed to the tasks of these grants, not all of them were supported. Several of them have been working on these projects as purely academic tasks.

PUBLICATIONS

Note: For all of the publications listed below:
Principal Author is the P.I., Ervin Y. Rodin

1. "Routing Airlift Aircraft By The Double Sweep Algorithm", (with Rink et. al.), Mathematical and Computer Modelling 30, pages 133-147, 1999

2. "Neural Network Augmented Anti-skid Controller for Transport Aircraft," (with Tunay and Amin) ,Proceedings of the 37th AIAA Aerospace Sciences Meeting and Exhibit, paper # AIAA 99-0260, 9 pp., 1999

3. "Simulation of Military Airfields," (with Cusick, et. al.), paper #AIAA-98-4822, Proc. of 7th AIAA/USAF/ NASA/ISSMO Symp. on Multidisciplinary Analysis and Optimization, St. Louis, MO, 1998

4. "Object Oriented Modeling of the Strategic Brigade Airdrop Operation," (with Grindey, et. al.), paper #AIAA-98-4881, Proc. of 7th AIAA/USAF/NASA/ISSMO Symp. on Multidisciplinary Analysis and Optimization, St. Louis, MO, 1998

5. "Implementation of NRMO to Study the Airlift Problem at Air Mobility Command," (with Rink, et. al.), paper #AIAA-98-4821, Proc. of 7th AIAA/USAF/NASA/ISSMO Symp. on Multidisciplinary Analysis and Optimization, St. Louis, MO, 1998.

6. "Traffic Prediction and Management via RBF Neural Nets and Semantic Control" (with Amin et al.), Computer Aided Civil and Infrastructure Engineering 13, pp.315-327, 1998.

7. "Operations Research in Intelligent Transportation Systems - A Semantic Control Approach" (with Garcia et al.) accepted for publication in the International Transactions on OR Journal, to appear in 2000

8. "Modeling and Robust Control Design for Aircraft Brake Hydraulics", (with Tunay et. al.), IEEE Transactions on Control Systems Technology 9/2, pages 319-329, 2001

INTERACTIONS/TRANSITIONS

Joint development with HQ/AMC at Scott AFB.

ATTACHMENTS

The abstracts of the 3 doctoral dissertations, as referenced above, are presented on the next three pages.

Simulation and Optimization of a Military Airfield System
by
Travis Cusick

ABSTRACT

The largest air transportation company in the world is administered by the Air Mobility Command (AMC) division of the United States Air Force stationed at Scott Air Force Base, IL. The AMC is responsible for managing our Air Force's capability to move personnel, equipment, and cargo during war time and peace time from any origin to any destination within its global system of airfields. The analysis group of the AMC employs sophisticated computer models and optimization packages to help them better understand the capabilities and limitation of the many types of resources making up this complex transportation system.

Part of this study describes the development of a computer model that is used to analyze the complex activities that occur at a military airfield in support of the many types of military operations. The model and resulting computer simulation are both known at BRACE, or Base Resource and Capabilities Estimator. BRACE is now used by the Air Force on a daily basis to analyze the capabilities of their many airfields throughout the world and it has been used to support several major policy changing studies.

Like many modern transportation systems, and airfield consists of many different resources that follow non-linear dynamics that can change both continuously and at discrete times. In order to attempt to optimize the resulting complex hybrid system, a new decomposition method is developed. The airfield system is decomposed into smaller non-hybrid subsystems that can be correctly modeled and optimized using queuing theory, optimal control, and other proven methods. The subsequent analysis and optimization results in improved heuristics for any of the airfield's major subsystems. To realize the benefits of the new heuristics, a feedback control paradigm is developed to control the parameters of the airfield system based upon the information gained by a system monitor.

Adaptations of Constraint Programming to Aircraft Scheduling Problems

by

Sanghyun Kim

ABSTRACT

Constraint programming offers a variety of modeling techniques that ease the challenging notion of solving combinatorial optimization problems. By adding problem-dependent constraints without having to modify the solution strategy, constraint programming provides several advantages over the traditional mathematical programming techniques. We uncover the underlying mechanism of constraint programming and extend our studies to scheduling problems such as the single-airport Ground Holding and Free flight problems, and the railway locomotive scheduling problem. Optimization techniques to solve Ground Holding and Free Flight problems play an eminent role in the airline industry. Comparison studies between the traditional mathematical programming models and the proposed constraint programming models are provided.

Furthermore, a different type of novel optimization technique is discussed, specifically simulation and optimization. Using simulation, the problem of Taxi Brake Select® is analyzed and a special type of artificial intelligence, namely reinforcement learning, is adapted in order to improve the cost and safety of the aircraft and to make the taxi brake system flexible to integrate different types of aircrafts.

Extremum-Seeking Based Antiskid Control and Functional Principal Components

by
Ilker Tunay

ABSTRACT

The first part of this work extends principal component analysis to random elements of abstract Hilbert spaces. Using only standard functional analysis, it is shown that the optimal PCA subspace is spanned by the eigenvectors of the covariance operator and the linear variety that minimizes average squared error contains the mean of the distribution. An immediate application of this principle is obtaining an optimal linear parametrization of a nonlinearly parameterized dynamical system, which is useful for adaptive control.

The second part describes the modeling of an electrohydraulic pressure servo valve and brake hydraulic system, and the design of an inner-loop controller which can be used with independent antiskid or auto-brake controllers. The effects of connecting lines on stability and performance are explicitly taken into account in control design by using analytical solutions to two-dimensional viscous compressible model of fluid motion in the pipe. The modal approximation technique is used in the simulations. In order to facilitate control design, singular perturbation analysis is employed to reduce the order of the model in a systematic fashion. Combining partial feedback linearization and linear H_∞ control, guaranteed stability robustness against oil parameter variations and component wear is achieved. The closed-loop response is almost linear, fas, sufficiently damped, consistent over the whole operating range and the asymmetry between filling and dumping is significantly reduced.

The third part gives an overview of extremum-seeking control and presents an antiskid controller for transport aircraft. The controller does not assume knowledge of tire-runway friction characteristics. Information about the local slope of the friction coefficient function is obtained from phase difference measurements of an injected sine wave. The Popov criterion is used to show robust stability. A realistic model of the MD-90 aircraft and brake system is described. The proposed controller is compared with the controller currently in service via simulations. The results indicate that the proposed controller has similar or better stopping performance, and operates much smoother without introducing strut vibrations.